FEEDING BEHAVIOUR OF THE SQUIRREL GLIDER IN REMNANT HABITAT IN BRISBANE

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The diet of the squirrel glider (*Petaurus norfolcensis*) was studied in a 45 ha forest remnant within an urban area close to Brisbane in south-east Queensland. Qualitative observations of feeding behaviour were conducted during each of 10 months between May 2002 and April 2003, on over 27 *P. norfolcensis* from at least 10 social groups. Four different feeding behaviours were recorded from 750 observations. Feeding from flowers accounted for 48% of the diet. Nectar and pollen were derived from 10 overstorey tree species, though forest red gum (*Eucalyptus tereticornis*) dominated because of its high abundance and protracted flowering period. Honeydew and lerp feeding accounted for 15% and 2% of all observations, respectively. Searching for arthropods accounted for 35% overall and occurred in 20 different tree species, where a range of substrates was used. Brushbox (*Lophostemon confertus*) was the most important; it was used in all seasons and accounted for 49% of these observations. These results contrast with assessment of the diet of *P. norfolcensis* at other sites where a greater range of broad food types was used. This may reflect the disturbed quality of the habitat at our site. However, these observations confirm the importance of eucalypt nectar in the diet of this species.

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AN animal’s diet will have a major influence on its life history, determining its use of habitat, reproductive capacity, social organisation and ultimately its population size (e.g., Emlen and Oring 1977; Caro 1989; Goldingay 2000). Describing a species’ diet is therefore fundamental to its management and conservation. An adequate description of the diet should be based on studies throughout a species’ geographic range because food resources may vary greatly in distribution and abundance over large spatial scales. Such studies should encompass different seasons so that seasonal variation in the diet is accommodated.

The squirrel glider (*Petaurus norfolcensis*) is a medium-sized petaurid marsupial whose range extends from central Victoria, through eastern New South Wales (NSW) and Queensland (Qld), up to Cape York Peninsula (Quin et al. 1996a). Detailed study of its diet has been conducted at a small set of locations in Victoria (Menkhorst and Collier 1987; Holland 1998) and at Bungawalbin Nature Reserve in north-east NSW (Sharpe and Goldingay 1998). These studies have shown that the diet typically contains plant and animal exudates, and arthropods. The diet in north-east NSW was heavily dominated by the nectar and pollen of *Banksia integrifolia* and various species of eucalypt (Sharpe and Goldingay 1998). Arthropods occupied a smaller but consistent component of the diet. Quin (1995) anecdotally reported a similar diet at Limeburner’s Creek Nature Reserve, approximately 400 km south of Bungawalbin. In Victoria, nectar and pollen were not widely used, possibly due to poor flowering at the time of the study, but *Acacia* gum and arthropods were commonly found in the diet (Menkhorst and Collier 1987). Further study of the diet is needed to enable important food resources of this species to be more fully identified.

The aim of this study was to describe the diet of *P. norfolcensis* for a site in south-east Queensland. The site chosen was an urban forest remnant, so describing the diet in such a context may provide insight to survival at sites subject to fragmentation and other forms of habitat disturbance.

METHODS

Study area

This study was conducted in remnant bushland that is part of Minnippi Parklands. The site is located approximately 10 km east of the Brisbane CBD. It contained approximately 45 ha of forest and was connected to other remnants of 20 – 30 ha by a narrow strip of trees along the adjoining Bulimba Creek. The habitat on the southern and south-eastern
sides extended into areas of open pasture. These areas were grazed by cattle while a part of the northern section was grazed by horses. The site is surrounded by a high density of residential development. It is bordered to the north by a shopping complex and industrial complex, to the west by a major arterial road and housing, and to the south by housing. To the east, the site is bordered by open pasture, open parkland containing some small bushland remnants and then bordered by the Gateway Freeway. The area is owned by Brisbane City Council, and lease-holders grazed horses and cattle there at the time of the study. We refer to the landscape context of our site as urban because the remnant is embedded well within an area dominated by residential development and its associated infrastructure.

The dominant overstorey species were brushbox (Lophostemon confertus), forest red gum (Eucalyptus tereticornis), northern grey ironbark (Eucalyptus siderophloia), broad-leaved paperbark (Melaleuca quinquenervia), smooth-barked apple (Angophora leiocarpa), narrow-leaved red gum (Eucalyptus seeana), pink bloodwood (Corymbia intermedia), broad-leaved ironbark (Eucalyptus fibrosa), scribbly gum (Eucalyptus racemosa), white mahogany (Eucalyptus carnea), swamp box (Lophostemon suaveolens). The understorey was sparse but consisted of black wattle (Acacia leirocalyx) and hickory wattle (Acacia aulacocarpa). Other tree species occurred within the study area but were uncommon. Belt transects (10 x 100 m) were placed through two parts of the study area and the relative abundance of different tree species was determined by identifying all trees > 10 cm diameter at breast height.

**Feeding observations**

A detailed trapping study was conducted across the site using 30 - 36 traps. This enabled most gliders to be given two ear-tags with reflective tape attached that provided a unique colour-code permitting individual recognition. A radio-collaring program began in May 2002 to enable gliders to be readily located at night. Eight adult *P. norfolcensis* (5 males, 3 females) were collared initially and this peaked at 14 in November. The radio-tracking program was maintained throughout the study with at least five *P. norfolcensis* carrying collars during each month of field work. During the study, 27 *P. norfolcensis* from > 10 groups carried collars for different periods of time. Collared individuals were located at least once each night. A red-masked 50 W spotlight and binoculars were used to observe gliders.

When gliders were located they were observed for a maximum of 10 min to record their feeding behaviour. Feeding observations for each glider were recorded no more frequently than once per hour. Many observations were also made of other *P. norfolcensis* without collars. Observations were conducted on a minimum of six individuals per field trip and were derived from more than 27 *P. norfolcensis* over the course of the study. The approach used was that of Sharpe and Goldingay (1998) and Quin et al. (1996b) where the diet is described by collating a series of qualitative records rather than timing the duration of feeding behaviours as recommended by Goldingay (1986). This approach allows the diet to be described for a larger number of gliders than is likely if feeding behaviours are timed.

The feeding behaviours identified were similar to those described by Goldingay (1986) and Sharpe and Goldingay (1998). They were flower licking (nectar and pollen feeding), branch licking (honeydew feeding), slow foliage gleaning in eucalypts (lerp and honeydew feeding), foliage licking in brushbox (honeydew feeding), rapid foliage gleaning (arthropod feeding), trunk and branch searching (arthropod feeding), bark peeling (arthropod and honeydew feeding), and nest predation (licking the contents from a bird’s egg). The food type when gliders were bark peeling or foliage gleaning was confirmed by close examination of analogous sites to where gliders fed. For example, fresh branchlets of fallen foliage can often be found under trees in which gliders engage in foliage gleaning.

**Flowering phenology**

Flowering trees in the study area were not specifically quantified. However, the substantial amount of time spent in the study area allowed the commencement and duration of flowering events to be recorded for most tree species within the period of study. Any bark shedding observed during observations was also noted. Although glider observations were not conducted in July 2002 and January 2003, short site visits enabled an assessment of which species were flowering.

**RESULTS**

A total of 750 feeding observations of *P. norfolcensis* were recorded during the 12-month period of the study. The number of observations each month ranged from 25 to 304 (Fig. 1). These were distributed across 6 - 15 individuals in each month (Table 1). Although some gliders contributed more observations than others in a given month, this was not overly pronounced and was not biased towards one sex. The number of individuals contributing records was > 10 in three of the 10 sample periods. The different feeding behaviours can be classed into one of five food types.
Table 1. The number of feeding observations per *P. norfolcensis* for each month of study in Brisbane during 2002-2003. Glider numbers do not represent specific individuals but the ranking of individuals from the highest to lowest number of records. Different individuals were studied in different months, though some were observed across several months. Unknown shows the number of records contributed by individuals that were not individually identified. No field work was conducted in July and January. There were 27 individuals that carried radio-collars across the study period.

![Graph showing feeding observations of *P. norfolcensis* in Brisbane. A single observation of egg feeding in August is not shown. Bars show the percentage of monthly feeding observations attributed to particular food types. Sample sizes are shown for each month. No data were collected in July 2002 and January 2003.]

**Nectar and pollen feeding**

Feeding in flowers accounted for 48% of all feeding observations. Flowers were the most important food resources in all months except May and October 2002 and March and April 2003 (Fig. 1). Autumn was characterised by low flower use in consecutive years. Flowering trees were present during all months of the study though the abundance of these species influenced how available this resource was (Table 2). *E. tereticornis* accounted for 55% of all nectar and pollen feeding (hereafter referred to as nectar...
Arthropod feeding

Arthropod feeding occurred throughout the year (Fig. 1). It accounted for 35% of all observations, and occurred in 20 different tree species as well as in dead standing trees (stags) (Fig. 3). Gliders were observed rapidly moving through the canopy, along primary and secondary branches, and on occasions within the foliage searching for arthropods. They moved and tilted their heads while climbing, indicating a visual search for arthropods. Gliders also took circuitous routes as they moved through trees. Flying insects such as moths were occasionally captured, such as in April when gliders appeared to deliberately stalk moths, which were abundant in Acacia spp. L. confertus was an important arthropod foraging resource, accounting for 49% of these observations. This tree accounted for 57% of 227 trees identified along the transects placed through the study area. A contingency table analysis revealed this tree species was used in proportion to its abundance when compared to all other trees counted ($\chi^2 = 2.64, df = 1, p = 0.10$). Gliders were recorded as arthropod feeding when observed peeling the bark of L. confertus. They were also observed rapidly moving throughout the canopy in search of arthropods in this species. P. norfolcensis often searched the dead branches of stags and large living trees, and amongst the common silkpod vines (Parsonsia stramina) growing on tree trunks, presumably looking for arthropods.

Bark shed was observed in L. confertus in autumn of both years. This occurred on the outer branches and particularly at the transition between the rough and smooth bark. Loose pieces of bark persisted in this location throughout the year, providing a good substrate for psyllids and other arthropods.

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Table 2. The observed flowering periods of the tree species found at Minnippi Parklands, near Brisbane. Relative species abundance: * = rare, ** = occasional, *** = moderately abundant, **** = highly abundant. A few species are not included because they were rare and did not flower. No glider observations were conducted in July and January.
Fig. 2. Percentage of observations in different tree species when *P. norfolcensis* were engaged in nectar and pollen feeding. Sample sizes are shown for each month.

Fig. 3. Frequency of use of different tree species when *P. norfolcensis* were engaged in arthropod feeding (n = 179). Mixed was where two species were used together.
small arthropods. Bark shed on the eucalypts in the study area occurred predominantly in November - December

**Honeydew feeding**

Honeydew feeding accounted for 15% of all observations. During October 2002, *L. confertus* produced a flush of new leaf growth. These new leaves were heavily infested by psyllids and honeydew was observed to be abundant on all leaves examined. Gliders were observed licking these leaves to harvest this form of honeydew. Black flying-foxes (*Pteropus alecto*) also made extensive use of this food resource in October and with up to six observed in the one tree. Honeydew was also obtained from *L. confertus* by gliders pealing back the loose bark that persisted along the branches and licking the exposed substrate. This accounted for 18% of the feeding observations in November and 59% in April (Fig. 1). Gliders were also observed to eat the psyllids producing this honeydew, due to the easy access to them under the flaking bark. Only where branch licking occurred was this recorded as honeydew.

A single *P. norfolcensis* was observed licking honeydew from the branches of *E. tereticornis* in September. These branches bore the tell tale sign of sooty mould and droplets of honeydew were observed glistening in the light of the spotlight (see Goldingay and Kavanagh 1995). This tree was suffering psyllid-induced dieback. Honeydew was also harvested from *E. tereticornis* and it shed its bark in November 2002. This accounted for 10% of the feeding observations at this time.

**Lerp feeding**

Small amounts of lerp feeding occurred in October, November and March (Fig. 1). A small number of observations were made of *P. norfolcensis* harvesting lerp from *C. intermedia, E. seeana* and *C. citriodora* in April 2003 but the majority of it occurred in *E. tereticornis*. Lerp feeding involved a very slow and methodical gleaning of the foliage. Lerp was confirmed by examining fallen foliage under the tree. It is likely that some honeydew was also harvested during this activity. Similar behaviour was also observed on two occasions in a species of *Ficus* in November and once in April.

**Bird nest predation**

A single *P. norfolcensis* was observed feeding on the egg of a noisy miner (*Manorina melanopechala*). The glider was positioned immediately above a nest in a *L. confertus*. It held the egg in its forelimbs close to its mouth for several minutes while it licked or sucked the contents. Then it dropped the egg shell to the ground. Another egg shell was found below the nest. Both discarded eggs were mostly intact but devoid of contents.

**DISCUSSION**

The diets of the petaurid gliders have been well studied compared to many other marsupials, and this is providing important insights into the ecology of these species. The best studied is the yellow-bellied glider (*Petaurus australis*). Its diet has been described in detail at six locations across the full width of its geographic range (Carthew et al. 1999). Such detailed assessment has revealed the relative importance of different food types. For example, eucalypt sap featured in the diet at every site and accounted for over 80% of feeding observations at each end of the geographic range (Quin et al. 1996b; Carthew et al. 1999). In contrast, nectar predominated at one site, but was relatively unimportant at several sites.

The diet of the widely distributed sugar glider (*Petaurus breviceps*) has been described at three locations. In Victoria, *Acacia* gum accounted for 43% of feeding observation time, arthropod searching 30% of time and eucalypt sap 11% of time (Smith 1982). No observations were made of nectar feeding although it was implicated in the diet from faecal analysis. On the Northern Tablelands of NSW, sap accounted for 38% of the feeding time, gum 3% of time, arthropods 22% of time and nectar 2% of time (Quin 1993). In marked contrast, nectar feeding in banksias and eucalypts accounted for 78% of feeding observation time and arthropod feeding 3% of time, on the mid-south coast of NSW (Howard 1989). Gum and sap were relatively unimportant, accounting for approximately 6% of feeding observation time. This demonstrates that *P. breviceps* is less reliant on eucalypt sap than *P. australis*, and that the relative importance of different food types to *P. breviceps* varies greatly across its geographic range, presumably in response to habitat differences.

The current study provides the third detailed assessment of the diet of *P. norfolcensis* based on direct observation of feeding. This description is based on 750 observations from over 25 individuals, over a 12-month period. These values are second only to Quin et al. (1996b) for comprehensiveness in such a dietary study. Nectar and pollen feeding accounted for 48% of the observations in Brisbane, derived from 10 tree species. More than 50% of these observations were of gliders licking the flowers of *E. tereticornis*. The magnitude of this value is inflated by the greater number of feeding records obtained in June when more field work was conducted compared to other months. However, 44% of all feeding observations were conducted during the five months of field work after *E. tereticornis* finished flowering.
in October 2002, including two months with > 100 observations, suggesting only a slight bias may be present.

Nectar and pollen accounted for 59% of feeding observations of *P. norfolcensis* at Bungawalbin Nature Reserve (Sharpe and Goldingay 1998), located approximately 240 km south of the site in Brisbane. At this latter location, *B. integrifolia* accounted for over 50% of these observations. Nectar was derived from five tree species, including *E. siderophloia* and *E. seeana*, which were also important in Brisbane. Although research at additional locations is required, the studies above suggest that nectar and pollen may be of particular importance to *P. norfolcensis*. It is likely that nectar and pollen predominate in the diet in north-east NSW and south-east Qld due to the forest types occupied which is similar to that in north-east NSW (see Sharpe and Goldingay 1998). This is likely to reflect the availability of highly favoured flowering species such as *E. tereticornis*. The only species which was not heavily used when in flower was *M. quinquenervia*. The heavy use of flowering trees when available is similar to that observed in northeast NSW. Menkhorst (1986) observed a *P. norfolcensis* feeding on eggs. We made a single observation of feeding on honeydew and lerp (18% of feeding observations) was observed but this was of a higher magnitude to that at Bungawalbin (3% of observations; Sharpe and Goldingay 1998). Only a small amount of feeding on honeydew accounted for only 15% of observations in Brisbane. It appeared that some trees in this urban remnant were under stress, which was associated with psyllid attack. This may have increased the availability of honeydew. In a similar way, trees in the linear remnant where Holland (1998) conducted his study may have been predisposed to psyllid attack and therefore were highly productive sources of honeydew. However, honeydew accounted for 36% of feeding observation time of *P. australis* at Bombala (Goldingay 1986; Carthew et al. 1999). Further investigation is required of whether trees in close proximity to edges are more likely to provide sources of honeydew.

The only other detailed account of the diet of *P. norfolcensis* was that by Menkhorst and Collier (1987), based on the analysis of faeces collected across several sites in Victoria. Their records indicated only occasional nectar feeding in eucalypts, although flowering was poor during their study. This contrasts sharply with the regular usage of eucalypt blossom in Brisbane and Bungawalbin. Menkhorst and Collier suggested that eucalypt sap and *Acacia* gum were the primary exudates ingested at their sites. *P. norfolcensis* in Brisbane made no use of sap or gum, despite the presence of potentially suitable sap species such as *C. intermedia* (see Sharpe and Goldingay 1998). Only a small amount of feeding on honeydew and lerp was observed but this was of a higher magnitude to that at Bungawalbin (3% of observations; Sharpe and Goldingay 1998).

Menkhorst and Collier (1987) detected feathers in the faeces of five individual *P. norfolcensis*. They suggested that feathers may have been ingested while feeding on eggs. We made a single observation of one *P. norfolcensis* consuming the contents of an egg of a noisy miner. Holland (2001) observed a *P. norfolcensis* feed on the eggs of a nesting bronzingew (Phaps chalcoptera) in Victoria. Winter (1966) observed a *P. norfolcensis* eat the eggs of a nesting magpie-lark (Grallina cyanoleuca) near Brisbane. Despite the common availability of bird nests and roosting birds in our study area, there were no other observations of such behaviour suggesting that such an item was indeed rare in the diet. Sharpe and Goldingay (1998) made no observations of egg feeding in northeast NSW.

Arthropods accounted for 34% of feeding observations on *P. norfolcensis* in Brisbane or 26% of observations at Bungawalbin (Sharpe and
Goldingay 1998). These levels are similar to *P. breviceps* at some sites; 30% (Smith 1982) and 22% (Quin 1993). Many of our observations of arthropod feeding involved what Smith (1982) referred to as mixed eucalypt feeding. This involved searching through the canopies of trees and was associated with a low frequency of arthropod capture. Menkhorst and Collier (1987) found that caterpillars and beetles were commonly used by *P. norfolcensis* in Victoria. Our observations suggest that *P. norfolcensis* commonly consumed these as well as moths and spiders. *P. norfolcensis* in Brisbane used 20 different tree species for arthropod searching. Of particular significance was the extensive use of *L. confertus*. Bark peeling and foliage gleaning by gliders were regularly observed in *L. confertus* throughout the year. Although this species was dominant throughout much of the study area and was used in proportion to its abundance, it has not been recorded as an important foraging substrate for *P. norfolcensis* before. In fact, Rowston et al. (2002) recorded a significant negative correlation between this tree species and glider numbers in south-east Qld. This assessment needs reviewing because it is unlikely that the importance observed at Minnippi is site specific.

An important finding in this study was that more tree species were used in nectar and arthropod feeding than recorded previously for a single site. This may contribute to the survival of *P. norfolcensis* within remnant habitat surrounded by urban development. A great variety of food types and overlapping flowering periods throughout the year may provide a buffer against anthropogenic impacts. However, *P. norfolcensis* commonly survives in remnant woodland with a much lower tree species richness (see Menkhorst et al. 1988; van der Ree 2002). Further study of the factors that enable *P. norfolcensis* to survive in fragmented habitat is needed.

Understanding a species’ diet is fundamentally important to understanding other aspects of its ecology. This is particularly important for species that are listed as threatened or of management emphasis, where perturbations to components of the habitat may disrupt food supply, adversely affect reproduction and result in higher mortality (e.g., Quin 1995; Sharpe 2004). The current study is a starting point for understanding the ecology of *P. norfolcensis* in fragmented habitat in an urban setting, but this information will also extend our understanding of this species in other parts of its range.

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